ROLL FOR ROLL FORMING AND METHOD THEREFOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a roll for roll forming and a roll forming method using the same, and more particularly, to a roll for roll forming and a roll forming method therefor, by which a strip of sheet material is continuously fed and passed between roll stands that are arranged continuously, and is sequentially formed so that the sectional shape of the sheet material becomes circular, and by welding both ends of the sheet material, a pipe is finally produced.

2. Description of the Related Art

Generally, in a roll forming process of a thick-wall pipe, uncoiling process is performed, and then a sheet of material is made to be flat in a leveling process. In order to improve welding, edge parts of the initial material are cut at an appropriate angle in an edge milling process. Then, by passing the sheet material through a break down roll, a cluster roll, and a pin pass roll several times, the sectional shape of the sheet material is made to be circular and then welding is performed. The outline of this roll forming process can be referred to U.S. Pat. No. 4,299,108.

A variety of rolls used in roll forming will now be briefly explained referring to attached drawings.

FIGS. 1a through 1c are sectional views of a break down roll, a cluster roll, and a pin pass roll, respectively, used in a roll forming process.

As shown in FIG. 1a, the break down roll 10 comprises a pair of an upper convex roll 12 and a lower concave roll 14. The convex roll 12 has a circumference surface which is convex, and the concave roll 14 has a circumference surface which is concave in a shape corresponding to the convex surface of the convex roll 12. If a sheet of material is passed between these convex roll 12 and concave roll 14, the contour of the sheet material is changed into the same as the circumference surfaces of the convex roll 12 and concave roll 14. Many pairs of the break down rolls 10 are used in the roll forming

process, and as the process is proceeding, the width and curvature of a break down roll being used become smaller. The present invention relates to this break down roll and a method using the same.

As shown in FIG. 1b, the cluster roll comprises two parts, each having one side with a concave part. The two parts are arranged in the left and in the right of a sheet of material so that the two parts face and pressure the sheet material passing out of the break down roll 10, from respective sides in order to change the shape of the sheet material. Also, many pairs of these cluster rolls 20 are used and as the process is proceeding, the side recess of a cluster roll being used becomes more circular. Each of these cluster rolls 20 are arranged between break down rolls 10.

The pin pass roll 30 shown in FIG. 1c makes the shape of the sheet material close to a circle and makes the interval between both ends of the sheet material even so that the ends can be welded well. The pin pass roll 30 comprises an upper roll 32 having a protruding pin and a lower part 34 having no pin. These rolls 30 are used in the post process after the break down roll 10 and cluster roll 20 processes.

FIGS. 2a through 2d are sectional views of examples of break down rolls.

In the roll forming process, the break down rolls 10 as shown in FIGS. 2a through 2d, are used. In the initial stage, the upper convex roll 12a, which is divided into a left part and a right part, and the lower concave roll 12a having a W-shaped circumference surface are used, as shown in FIG. 2a. This is to form both end parts of the sheet material in the initial stage. However, the rolling forming process does not necessarily use the break down roll 10 as shown in FIG. 2a.

After the sheet material passes the break down roll 10 shown in FIG. 2a, a convex roll 12b having a relatively longer width and bigger curvature and a concave roll 14b corresponding to the convex roll 12b, as shown in FIG. 2b, are used. As the process is proceeding, in order of FIG. 2c and FIG. 2d, convex rolls 12c and 12d having smaller width and curvature and concave rolls 14c and 14d corresponding to the convex rolls 12c and 12d, respectively, are used.

FIG. 3.is a diagram showing a roll forming process in which a sheet of material is being formed. That is, the sheet material 40 is in a flat plate state in the initial stage but after passing the break down rolls 10, cluster rolls 20, and pin pass rolls 30 several times, the sectional shape of the sheet material is gradually changed to a circular one. In FIG. 3, the sheet material 40 in a flat plate state is formed to have a circular sectional shape through total 14 steps from F1 to FS7.

FIG. 4 is a sectional view of a pipe produced by roll forming.

Through the process described above, the strip of the sheet material 40 is changed to have a circular sectional shape, and then the both ends of the sheet material 40 facing each other are welded such that a pipe 50 having a welding seam 52 as shown in FIG. 4 is produced. This pipe 50 is made to have a desired diameter by a drawing process, or is reprocessed and made to have a complex shape by a hydroforming process, in which a tube preliminary formed is mounted inside a mould, and fluid is filled in the inside to press fully so that a desired shape is produced.

However, in the pipe 50 produced by the prior art, in the roll forming process, the bottom center part 54 is continuously pressured by the upper rolls and lower rolls of many break down rolls 10 and is plastic deformed by compression such that the part suffers more serious work hardening than other parts. The length of the bottom center part 54 suffering serious work hardening is about 10~15 percent of the circumference of the pipe 50, that is, the entire width of the sheet material (40). Also, in other parts, the degree of work hardening occurs differently with respect to location.

The part suffering serious work hardening has inferior material properties and workability of the part is greatly degraded. When the degree of work hardening is not even, the material properties and workability are degraded.

That is, when the pipe 50 produced by the prior art is used, cracks often appear in the vicinity of the bottom center part 54 in the hydroforming process. In addition, in the drawing process, the percent reduction in area is smaller due

to the work hardening of the part 54 and the frequency of processes such as heating increases.

Furthermore, even if it may not cause a problem in the hydroforming process, the work hardening of the bottom center part 54 of the pipe is one of the factors degrading the quality of finished products after processing.

SUMMARY OF THE INVENTION

The present invention provides a roll for roll forming which prevents work hardening of a predetermined part of roll formed sheet material that degrades the material properties and reprocessing properties of products.

The present invention also provides a roll forming method which prevents work hardening of a predetermined part of roll formed sheet material that degrades the material properties and reprocessing properties of products.

According to an aspect of the present invention, there is provided a roll for roll forming, which has an axis coupling part for coupling with a rotation axis, and a circular sectional shape, and pressures and deforms a sheet of material passing between two rolls for roll forming, the roll comprising a plurality of pressure parts which are formed along the circumference of the circumference surface of the roll, are disposed with intervals in the width direction, and divide and pressure the sheet material passing by; and a non-pressure part which is disposed between the pressure parts and is to not pressure partially the sheet material passing by, wherein the pressure parts and non-pressure part are disposed symmetrically on the left side and right side.

It is preferable that the non-pressure part is formed in the form of a groove, the non-contact length of the roll and the sheet material is less than 60% of the effective length of the roll, and equal to or more than 10% of the width of the sheet material.

The plurality of the pressure parts and non-pressure part may be formed alternately in the width direction.

According to another aspect of the present invention, there is provided a roll forming method by which while sheet material is sequentially passed between a plurality of convex rolls and a plurality of concave rolls, the sheet

material is pressured so that the sectional shape of the sheet material is formed as desired, wherein the plurality of convex rolls are arranged with intervals, and have convex circumference surfaces, and the curvatures of the convex rolls are sequentially diminishing, and the plurality of concave rolls are arranged neighboring the convex rolls to make respective roll pairs with corresponding convex rolls, and have concave circumference surfaces corresponding to the circumference surface of the convex rolls, respectively, the roll forming method comprising dividing and disposing a pressure part for pressuring the sheet material passing by, and a groove-shaped non-pressure part for not pressuring the sheet material passing by, on the circumference surface of the convex roll or the concave roll, so that the frequency of pressure applied to at least one part of the sheet material, which passes through the roll pairs, by the roll pairs is reduced in order to reduce work hardening of the at least one part of the sheet material.

It is preferable that the pressure part formed on one roll pair is disposed so that the pressure part does not overlap the pressure part of another roll pair equal to or more than (the number of roll pairs - 2) times and by doing so, the frequency of pressure applied to each part of the sheet material passed through is less than the number of the roll pairs.

Preferably, the pressure part formed on one roll pair except the parts corresponding to both ends of the sheet material is disposed so that the pressure part overlaps the pressure part of another roll pair at a roughly identical frequency, and by doing so, the frequency of pressure applied to each part of the sheet material except both ends of the sheet material has a roughly identical distribution in the width direction of the sheet material.

According to still another aspect of the present invention, there is provided a roll forming method by which while sheet material is sequentially passed between a plurality of convex rolls and a plurality of concave rolls, the sheet material is pressured so that the sectional shape of the sheet material is formed to a circle and parts of the sheet material facing each other are welded to produce a pipe, wherein the plurality of convex rolls are arranged with intervals, and have convex circumference surfaces, and the curvatures of the

convex rolls are sequentially diminishing, and the plurality of concave rolls are arranged neighboring the convex rolls to make respective roll pairs with corresponding convex rolls, and have concave circumference surfaces corresponding to the circumference surface of the convex rolls, respectively, the roll forming method comprising dividing and disposing a pressure part for pressuring the sheet material passing by, and a groove-shaped non-pressure part for not pressuring the sheet material passing by, on the circumference surface of the convex roll or the concave roll, and by adjusting the frequency of pressure applied to each part of the sheet material by roll pairs formed with the convex rolls and the concave rolls, adjusting the degree of work hardening of each part of a finished pipe.

Also, in this case, the pressure part formed on one roll pair may be disposed so that the pressure part does not overlap the pressure part of another roll pair equal to or more than (the number of roll pairs - 2) times and by doing so, the frequency of pressure applied to each part of the sheet material passed through is less than the number of the roll pairs.

It is preferable that the pressure part formed on one roll pair except the parts corresponding to both ends of the sheet material is disposed so that the pressure part overlaps the pressure part of another roll pair at a roughly identical frequency, and by doing so, the frequency of pressure applied to each part of the sheet material except both ends of the sheet material has a roughly identical distribution in the width direction of the sheet material.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIGS. 1a through 1c are sectional views of a break down roll, a cluster roll, and a pin pass roll, respectively, used in a roll forming process;

FIGS. 2a through 2d are sectional views of examples of break down rolls;

FIG. 3 is a diagram showing a roll forming process in which a sheet of

material is being formed;

FIG. 4 is a sectional view of a pipe produced by roll forming;

FIG. 5 is a perspective view of an embodiment of a roll for roll forming according to the present invention;

FIG. 6 is a perspective view of another embodiment of a roll for roll forming according to the present invention;

FIG. 7 is a section view of a modified embodiment of a convex roll of FIG. 5;

FIG. 8 is a sectional view of a modified embodiment of a concave roll of FIG. 6;

FIG. 9 is a sectional view of a state where a sheet of material passes between the convex roll of FIG. 5 and the concave roll of FIG. 6;

FIGS. 10a through 10d are sectional views of combinations of modified embodiments, respectively, of rolls for roll forming according to the present invention; and

FIG. 11 is a conceptual diagram for explaining a roll forming method according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 5 is a perspective view of an embodiment of a roll for roll forming according to the present invention.

The roll shown in FIG. 5 is a convex roll 110 used as one of upper rolls of a break down roll. An axis coupling part 111 for coupling with a rotation axis is formed at the rotation center of the roll 110 and the circumference surface of the roll 110 is divided into pressure part 113 and non-pressure part 115.

Pressure part 113 is disposed along the circumference of the circumference surface of the convex roll 110 and is a part to pressure corresponding part of passing sheet material. It is preferable that edge part of this pressure part 113 is round-processed so that no scratch is made on the sheet material being pressured. A plurality of this pressure parts 113 are formed with intervals and are symmetrically disposed on the left side and right side. The width, number, position, and the like of this pressure part 113 can be

adjusted in line with those of pressure parts and non-pressure parts of other rolls arranged in the same roll forming apparatus.

Neighboring the pressure part 113, the non-pressure part 115 is formed. The non-pressure part 115 is also disposed along the circumference of the circumference surface of the convex roll 110 and in parallel with the pressure part 113. This non-pressure part 115 is for not pressuring corresponding part of passing sheet material. The non-pressure parts 115 are also symmetrically disposed on the left side and right side and are formed in the form of a groove. The width, number, position, and the like of this non-pressure part 115 can be adjusted in line with those of pressure parts and non-pressure parts of other rolls arranged in the same roll forming apparatus. The width, number, position, and the like of pressure parts and non-pressure parts formed on other rolls will be explained in detail later.

FIG. 6 is a perspective view of another embodiment of a roll for roll forming according to the present invention.

The roll shown in FIG. 6 is a concave roll 120 used as one of lower rolls of a break down roll. Also, an axis coupling part 121 for coupling with a rotation axis is formed at the rotation center of the roll 120 and the circumference surface of the roll 120 is divided into pressure part 123 and non-pressure part 125. Here, the pressure part 123 and non-pressure part 125 are also formed on the concave circumference surface of the concave roll 120, and except this, other things are the same as explained referring to FIG. 5.

FIG. 7 is a section view of a modified embodiment of a convex roll of FIG. 5.

The convex roll 110a shown in FIG. 7 is installed in a back-end process after the convex roll 110 of FIG. 5, and is also to pressure sheet material for plastic deformation. Compared to the convex roll 110 of FIG. 5, the convex roll 110a has a short width and a smaller curvature. Here, when the same number of pressure parts 113 and non-pressure parts 115 as in FIG. 5 are disposed, the widths of the pressure part 113 and non-pressure part 115 are also shorter than those of the convex roll 110 of FIG. 5.

FIG. 8 is a sectional view of a modified embodiment of a concave roll of

FIG. 6.

The concave roll 120a shown in FIG. 8 is installed in a back-end process after the concave roll 120 of FIG. 6, and compared to the concave roll 120 of FIG. 6, has a short width and a smaller curvature. Other things are the same as explained in FIG. 6.

FIG. 9 is a sectional view of a state where a sheet of material passes between the convex roll of FIG. 5 and the concave roll of FIG. 6.

Referring FIG. 9, on the circumference surface of the upper convex roll 110, pressure parts 113 and non-pressure parts 115 are alternately formed, and also, on the lower concave roll 120 facing the convex roll 110, pressure parts 113 and non-pressure parts 115 are alternately formed on corresponding locations. While passing between these convex roll 110 and the concave roll 120, the sheet material 40 is plastic deformed at the curvature of the circumference surface of the convex roll 110 and concave roll 120. In order not to leave roll traces on the sheet material 40, the pressure (σ_y) applied to the sheet material 40 should be less than the yield strength (σ_a) of the material. That is, $\sigma_a > \sigma_y$.

Here, if the shear deformation resistance of the sheet material 40 is k = 173.2(N/mm^2); the contact length between the sheet material 40 and the rolls 110 or 120 when there is no non-pressure part 113 is 2b = 132.2(mm); the thickness of the sheet material 40 is 2t = 4.5(mm); the friction coefficient of the sheet material 40 and the rolls 110 and 120 is μ = 0.1; the forming curvature radius of the central surface of the sheet is r = 263.18(mm); the maximum rotational radius of the convex roll 110 is r_1 = 129.68(mm); and the rotational radius of the edge part of the sheet material 40 is r_3 = 120(mm), the forming load is expressed as the following equation 1:

$$P = k \cdot b \cdot t2\{\cos(b/r)\ \mu\} \cdot \{4/r + 1/r_1 + \cos(b/r)/r_3\} = 16{,}418(N) \ldots\ldots(1)$$

Since $\sigma_y = P/(2b \times 1)$, if the yield strength of the sheet material is σ_a = 306(Mpa), the contact length 2b between the sheet material 40 and rolls 110 or 120 when the pressure applied to the sheet material should be equal to or

greater than 53.65(mm) so that the pressure (σ_y) applied to the sheet material 40 does not exceed the yield strength(σ_a) of the material. This means that the length should be 40 percent or more of the contact length (hereinafter, referred to as the effective length (L) of a roll) when there is no non-pressure part 115 and 125, which means that the maximum contact length that can be formed by the non-pressure part 115 and 125 should be less than 60 percent.

FIGS. 10a through 10d are sectional views of combinations of modified embodiments, respectively, of rolls for roll forming according to the present invention.

Depending on cases, as shown in FIG. 10a, in order to form a roll, the pressure parts 113 and 123 and non-pressure parts 115 and 125 of the upper convex roll 110b and the lower concave roll 120b may be formed alternately and more densely than the roll of FIG. 9. Of course, when necessary, the non-pressure part 115 and 125 may be formed on only one of the convex roll 110b and the concave roll 120b and not formed on the other.

As shown in FIG. 10b, on the lower concave roll 14, the non-pressure part is not formed and the prior art roll is used as is, and only at the center of the convex roll 110c, the non-pressure part 115 is formed and pressure parts 113 are formed at both sides of the non-pressure part 115, and then the upper convex roll 110c can be arranged at a desired position of the roll forming apparatus.

In addition, as shown in FIG. 10c, the non-pressure part is not formed on the lower concave roll 14, and three non-pressure parts 115 are formed around the center of the upper convex roll 110d and pressure parts 113 are formed between the non-pressure parts 115 and at both sides of the non-pressure parts 115. Then, the upper convex roll 100d can be arranged at a desired position of the roll forming apparatus.

When necessary, as shown in FIG. 10d, the non-pressure part is not formed on the upper convex roll 12, and the prior art roll is used as is, and only at the center of the concave roll 120c, the non-pressure part 125 is formed and pressure parts 123 are formed at both sides of the non-pressure part 125, and then the lower concave roll 120c can be arranged at a desired position of the

roll forming apparatus.

FIG. 11 is a conceptual diagram for explaining a roll forming method according to the present invention.

In FIG. 11, there are four line diagrams and one graph in an orderly manner. Here, when the sheet material 40 passes along the first break down roll described above, the sheet material 40 is divided into and expressed as a pressure area 43 and a non-pressure area 45 in the first line diagram 131 on the top. This is the same state as the circumference surface of part of the convex roll or the concave roll of the first break down roll. That is, the pressure area 43 corresponds to the pressure part 113 and 123 of the first roll and the non-pressure area 44 corresponds to the non-pressure part 115 and 125 of the first roll.

The second line diagram 132 divides and expresses the pressure area 43 and non-pressure area 45 when the sheet material passes along the second break down roll. This is the same state as the circumference surface of part of the convex roll or the concave roll of the second break down roll. Here, also, the pressure area 43 corresponds to the pressure part 113 and 123 of the second roll and the non-pressure area 44 corresponds to the non-pressure part 115 and 125 of the second roll. This is the same in the third and fourth line diagrams 133 and 134.

The graph 135 at the bottom shows the distribution in the width direction of frequencies of pressures applied to the sheet material 40 when the sheet material 40 passes all pairs of rolls. This is the same as the distribution in the width direction of cumulative pressure applied to each part of the sheet material 40.

That is, in each of the rolls which are sequentially arranged, the pressure parts 113 and 123 and the non-pressure parts 115 and 125 are alternately disposed so that the frequency of pressure or cumulative pressure applied to each part are uniformly distributed. Then, predetermined part of sheet material is not excessively work hardened and the quality of products becomes even.

In order to get the frequency of pressure or cumulative pressure applied

to each part of the sheet material 40 as desired, the forming positions and width of the pressure parts 113 and 123 and the non-pressure parts 115 and 125 formed on each roll need to be adjusted considering the frequency of contacts of the pressure parts in connection with neighboring rolls. That is, by appropriately combining and disposing the pressure parts and non-pressure parts formed on each roll, a variety of modifications different from that in FIG. 11 can be implemented.

As shown from the above description, rolls for roll forming and the roll forming methods according to the present invention reduces work hardening in pipe material in the roll forming process.

Also, the rolls for roll forming and the roll forming methods according to the present invention makes work hardening occur evenly on the entire surface of a pipe.

That is, when the rolls for roll forming and the roll forming methods according to the present invention are used, work hardening in roll forming material or a pipe occurs less, and the quality of the pipe is uniform such that the reprocessing properties of a pipe in hydroforming or drawing improves greatly.

When work hardening occurs less and the quality of a pipe is uniform, pipe cracks do not appear in the hydroforming process and the number of processes in the drawing process can be reduced from that of the prior art.